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(54) **WAFER HANDLING CHAMBER WITH MOISTURE REDUCTION**

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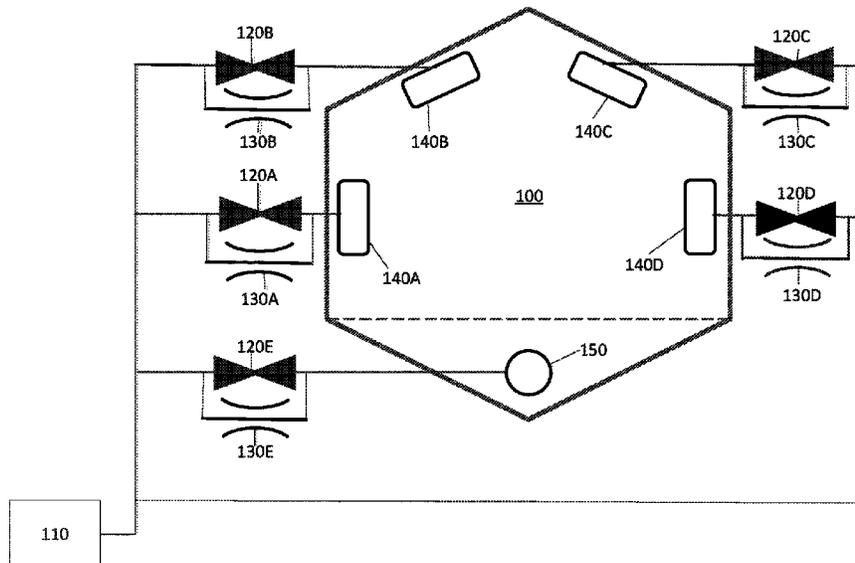
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(57) **ABSTRACT**

An apparatus and method for reducing moisture within a wafer handling chamber is disclosed. The moisture reduction results in reduced oxidation of a wafer. The moisture reduction is made possible through use of valves and purging gas. Operation of the valves may result in improved localized purging.

20 Claims, 2 Drawing Sheets



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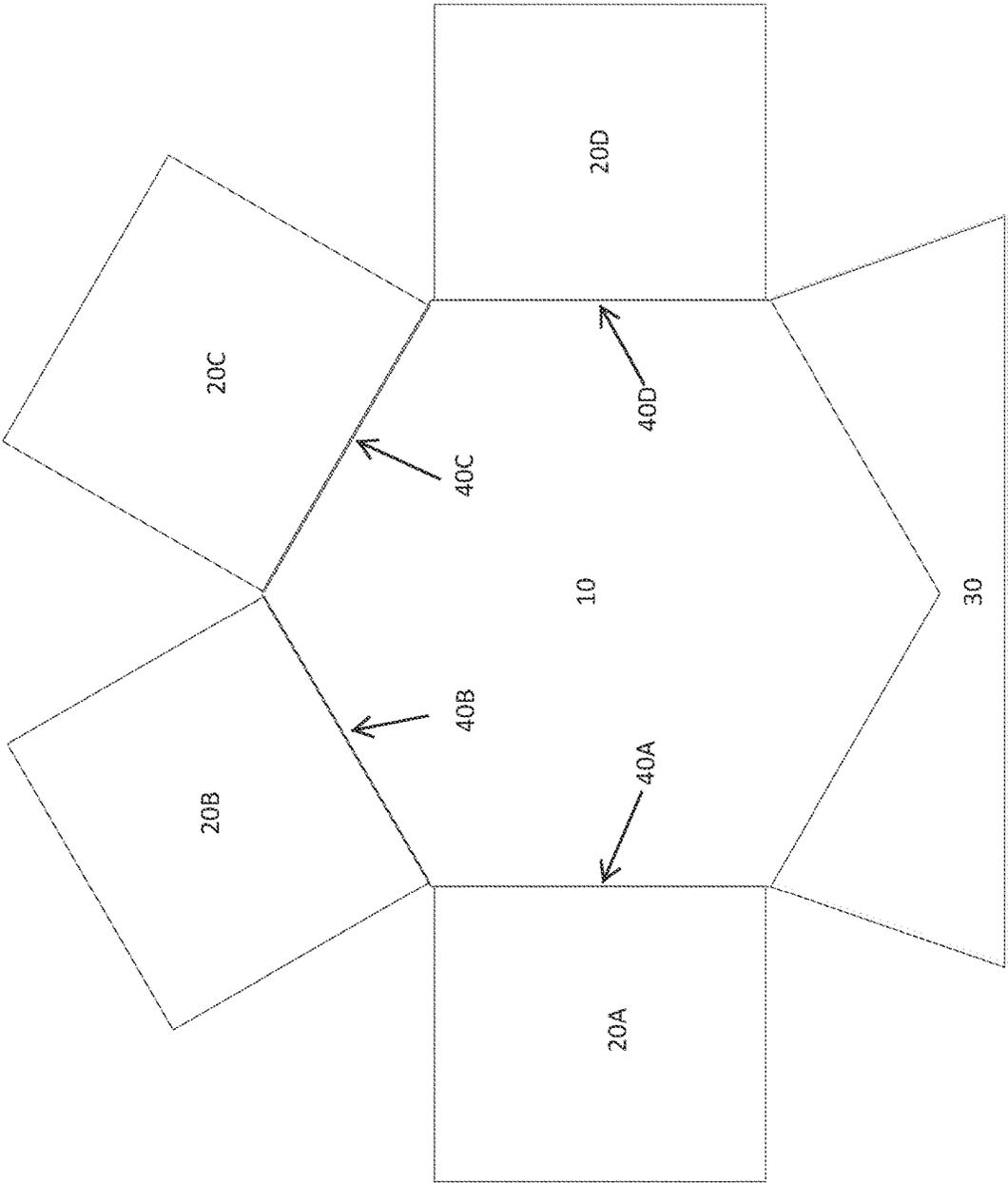


FIG. 1

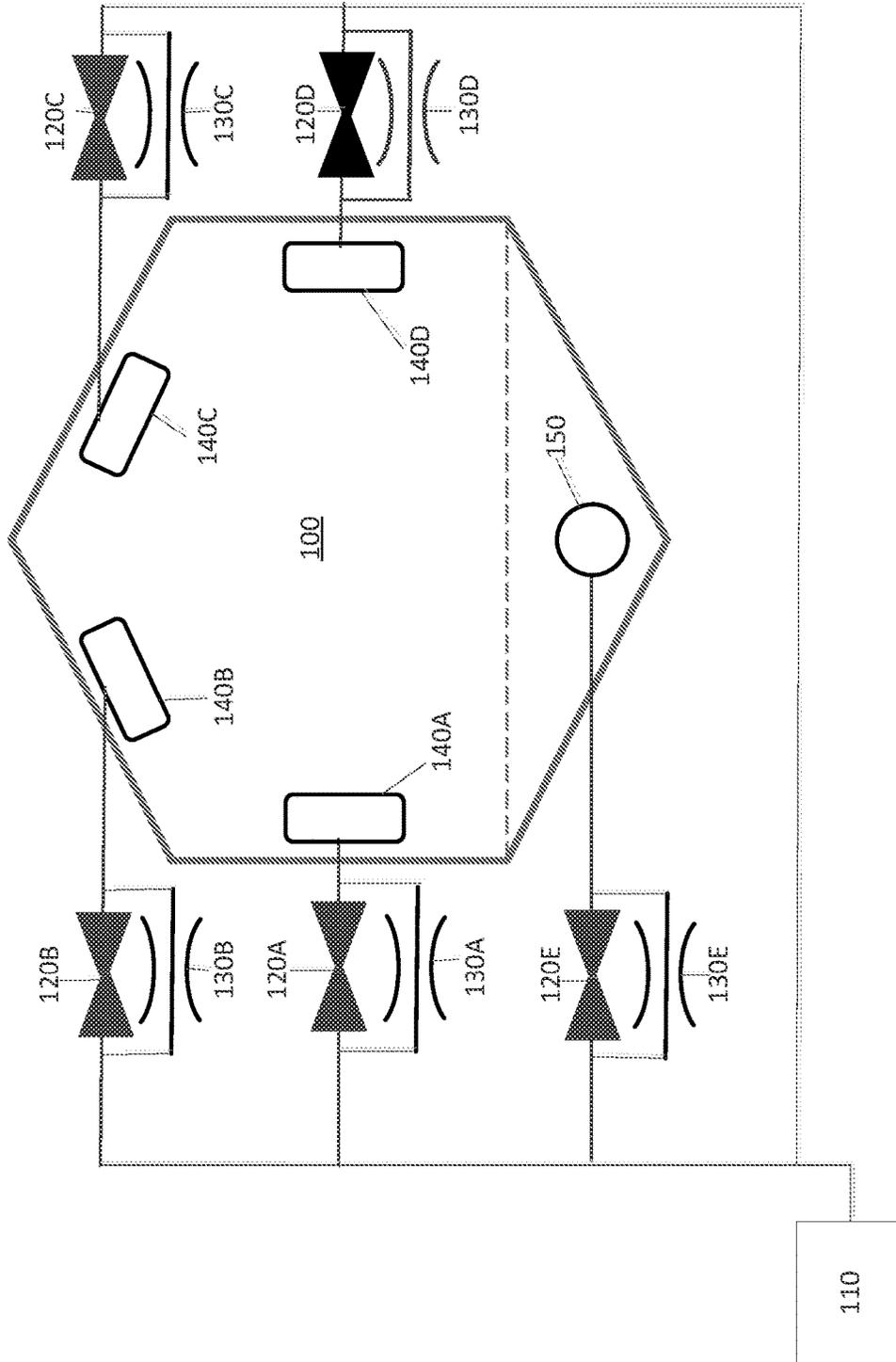


FIG. 2

1

**WAFER HANDLING CHAMBER WITH
MOISTURE REDUCTION****CROSS-REFERENCE TO RELATED
APPLICATIONS**

This application is a Continuation of, and claims priority to and the benefit of, U.S. patent application Ser. No. 16/423,824, filed May 28, 2019 and entitled "WAFER HANDLING CHAMBER WITH MOISTURE REDUCTION," which is a Non-Provisional of, and claims priority to and the benefit of, U.S. Ser. No. 62/680,465 filed Jun. 4, 2018 and entitled "WAFER HANDLING CHAMBER WITH MOISTURE REDUCTION," both of which are hereby incorporated by reference herein.

FIELD OF THE INVENTION

The present disclosure generally relates to semiconductor processing tools. More particularly, the disclosure relates to a wafer handling mechanism with a purge capability to reduce moisture around a wafer.

BACKGROUND OF THE DISCLOSURE

Wafers can travel through several different chambers during processing. For example, a wafer may go from a cassette in which the wafer is stored, into a wafer handling chamber. The wafer may go from the wafer handling chamber into a reaction chamber. In this process, moisture may accumulate on the wafer, resulting in oxidation of the wafer. Oxidation is undesirable for forming unwanted products on the wafer. In addition, oxidation may increase resistivity, change work function, and change nucleation of subsequent deposition.

Previous approaches have involved purging nitrogen gas as the wafer travels through the different chambers as well as adjusting a pressure of the chamber. Adjusting the pressure of the chamber may require changing the ambient conditions, which may cause a delay in waiting for a next wafer to be brought back to equilibrium. In addition, an ability to reduce the pressure in the chamber is limited by pumping capacity. Furthermore, increasing the flow of purging nitrogen gas is limited also by pumping capacity. The oxidation may result in increased non-uniformity of a tuning voltage of the wafer.

Additional issues with prior approaches include increased operation expense due to the reduction of moisture permeation. In addition, reducing incoming moisture that adheres to the wafer means that a degassing step is required, increasing expense and decreasing throughput. Furthermore, moisture can also enter the chamber through load locks, which may end up in oxidation on the wafer. As a result, it is desirable to reduce moisture in various chambers with an aim to reduce the amount of oxidation occurring on the wafer.

SUMMARY OF THE DISCLOSURE

For purposes of summarizing aspects of the invention and the advantages achieved over the related art, certain objects and advantages of the invention are described in this disclosure. Of course, it is to be understood that not necessarily all such objects or advantages may be achieved in accordance with any particular embodiment of the invention. Thus, for example, those skilled in the art will recognize that the invention may be embodied or carried out in a manner

2

that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other objects or advantages as may be taught or suggested herein.

In various embodiments, a wafer handling chamber configured for handling a semiconductor substrate may comprise a housing; a first gate valve disposed on the housing, wherein the first gate valve may be configured to allow a semiconductor substrate to pass and enter into the housing; a first injector port disposed proximate the first gate valve; a first isolation valve disposed outside the housing; a first flow restrictor coupled to the first isolation valve, wherein the first isolation valve and the first flow restrictor adjust an amount of a purge gas flowing to the first injector port; a loadlock injector port disposed within the housing; a loadlock isolation valve disposed outside the housing; a loadlock flow restrictor coupled to the loadlock isolation valve, wherein the loadlock isolation valve and the loadlock flow restrictor adjust an amount of the purge gas flowing to the loadlock injector port; and/or a flow controller configured to adjust an amount of purge gas flowing to the housing. In various embodiments, closing the first isolation valve may result in a reduced amount of the purge gas flowing to the first injector port; and/or closing the loadlock isolation valve may result in a reduced amount of the purge gas flowing to the loadlock injector port. In various embodiments, the purge gas may comprise at least one of: nitrogen (N₂); argon (Ar); hydrogen (H₂); and krypton (Kr).

In various embodiments, the chamber may further comprise a second gate valve disposed on the housing, wherein the second gate valve may be configured to allow a semiconductor substrate to pass and enter into the housing; a second injector port disposed near the second gate valve; a second isolation valve disposed outside the housing; and/or a second flow restrictor coupled to the second isolation valve, wherein the second isolation valve and the second flow restrictor may adjust an amount of a purge gas flowing to the second injector port. In various embodiments, the chamber may further comprise a third gate valve disposed on the housing, wherein the third gate valve may be configured to allow a semiconductor substrate to pass and enter into the housing; a third injector port disposed near the third gate valve; a third isolation valve disposed outside the housing; and/or a third flow restrictor coupled to the third isolation valve, wherein the third isolation valve and the third flow restrictor may adjust an amount of a purge gas flowing to the third injector port. In various embodiments, the chamber may further comprise a fourth gate valve disposed on the housing, wherein the fourth gate valve may be configured to allow a semiconductor substrate to pass and enter into the housing; a fourth injector port disposed near the fourth gate valve; a fourth isolation valve disposed outside the housing; and/or a fourth flow restrictor coupled to the fourth isolation valve, wherein the fourth isolation valve and the fourth flow restrictor adjust an amount of a purge gas flowing to the fourth injector port.

In various embodiments, closing each of the first isolation valve and the first gate valve, the second isolation valve and the second gate valve, the third isolation valve and the third gate valve, the fourth isolation valve and the fourth gate valve, and the loadlock isolation valve may result in an even distribution of gas to the first injector port, the second injector port, the third injector port, the fourth injector port, and the loadlock injector port. In various embodiments, opening only the first isolation valve and the first gate valve may result in an increased localized purging at the first injector port.

In various embodiments, the chamber may further comprise a ring of injector ports disposed within the housing. In various embodiments, the ring of injector ports may be selectively operated to allow purging at a particular injector port to be turned on and off. In various embodiments, the flow controller may comprise at least one of: a mass flow controller or a pressure flow controller.

In various embodiments, a reaction system configured for depositing a film on a semiconductor substrate may comprise a first reaction chamber configured to flow at least one gas onto a semiconductor substrate to form a film on the semiconductor substrate; and a wafer handling chamber coupled to the first reaction chamber. In various embodiments, the wafer handling chamber may comprise a housing; a first gate valve disposed on the housing, wherein the first gate valve may be configured to allow a semiconductor substrate to travel between the first reaction chamber and the wafer handling chamber; a first injector port disposed proximate the first gate valve; a first isolation valve disposed outside the housing; a first flow restrictor coupled to the first isolation valve, wherein the first isolation valve and the first flow restrictor adjust an amount of a purge gas flowing to the first injector port; a loadlock injector port disposed within the housing; a loadlock isolation valve disposed outside the housing; a loadlock flow restrictor coupled to the loadlock isolation valve, wherein the loadlock isolation valve and the loadlock flow restrictor may adjust an amount of the purge gas flowing to the loadlock injector port; and/or a flow controller configured to adjust an amount of purge gas flowing to the housing. In various embodiments, closing the first isolation valve may result in a reduced amount of the purge gas flowing to the first injector port; and/or closing the loadlock isolation valve may result in a reduced amount of the purge gas flowing to the loadlock injector port. In various embodiments, the flow of the purge gas may occur at the first injector port when the first gate valve is open and the semiconductor substrate may travel between the first reaction chamber and the wafer handling chamber.

In various embodiments, the reaction system may further comprise a second reaction chamber configured to flow at least one gas onto a semiconductor substrate to etch a film on the semiconductor substrate. In various embodiments, the purge gas may comprise at least one of: nitrogen (N_2); argon (Ar); hydrogen (H_2); and krypton (Kr). In various embodiments, flowing the purge gas through the first injector port may result in a lower oxygen content in the film on the semiconductor substrate. In various embodiments, the flow controller may comprise at least one of: a mass flow controller or a pressure flow controller.

All of these embodiments are intended to be within the scope of the invention herein disclosed. These and other embodiments will become readily apparent to those skilled in the art from the following detailed description of certain embodiments having reference to the attached figures, the invention not being limited to any particular embodiment(s) disclosed.

BRIEF DESCRIPTION OF THE FIGURES

While the specification concludes with claims particularly pointing out and distinctly claiming what are regarded as embodiments of the invention, the advantages of embodiments of the disclosure may be more readily ascertained from the description of certain examples of the embodiments of the disclosure when read in conjunction with the accompanying drawings, in which:

FIG. 1 is an illustration layout of a semiconductor processing machine in accordance with at least one embodiment of the invention.

FIG. 2 is an illustration of a wafer handling chamber in accordance with at least one embodiment of the invention.

It will be appreciated that elements in the figures are illustrated for simplicity and clarity and have not necessarily been drawn to scale. For example, the dimensions of some of the elements in the figures may be exaggerated relative to other elements to help improve understanding of illustrated embodiments of the present disclosure.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Although certain embodiments and examples are disclosed below, it will be understood by those in the art that the invention extends beyond the specifically disclosed embodiments and/or uses of the invention and obvious modifications and equivalents thereof. Thus, it is intended that the scope of the invention disclosed should not be limited by the particular disclosed embodiments described below.

A semiconductor wafer processing system may comprise a number of different chambers. FIG. 1 illustrates a representative semiconductor wafer processing system. The system may comprise a wafer handling chamber 10, a number of reaction chambers 20A-20D, and a loadlock chamber 30. A semiconductor wafer may first enter the system from a cassette of wafers into the loadlock chamber 30. A gate valve disposed between the loadlock chamber 30 and the wafer handling chamber 10 may be lowered so that the semiconductor wafer may enter into the wafer handling chamber 10. Additional gate valves may be disposed between the wafer handling chamber 10 and the reaction chambers 20A-20D. The additional gate valves may include a first gate valve 40A, a second gate valve 40B, a third gate valve 40C, and a fourth gate valve 40D.

The reaction chambers 20A-20D may be assigned to perform different deposition steps. For example, the reaction chamber 20A may be used for a film deposition step on the semiconductor wafer. The semiconductor wafer may then travel to the reaction chamber 20B (via the wafer handling chamber 10), where the semiconductor wafer may undergo a film etch step or other step.

When the semiconductor wafer travels between the wafer handling chamber 10 and the different reaction chambers 20A-20D as well as the loadlock chamber 30, the semiconductor wafer may be purged with nitrogen gas, for example. Other gases that may be used include argon or krypton, for example. The effect of this purging may result in lower oxygen content in a deposited film on the semiconductor wafer.

FIG. 2 illustrates a wafer handling chamber 100 in accordance with at least one embodiment of the invention. The wafer handling chamber 100 may comprise a flow controller 110, a plurality of isolation valves 120A-120E, a plurality of flow restrictors 130A-130E, a plurality of injector ports 140A-140D, and a loadlock injector port 150.

The flow controller 110 is connected to and controls an amount of gas flowing to the plurality of isolation valves 120A-120E and the plurality of flow restrictors 130A-130E via flow lines. The flow controller 110 may comprise a digital mass flow controller manufactured by Horiba or a pressure flow controller. The plurality of isolation valves 120A-120E may comprise DP series valves manufactured by Swagelok. The plurality of flow restrictors 130A-130E

5

may be restrictors manufactured by Lenox. Both the plurality of isolation valves **120A-120E** and the plurality of flow restrictors **130A-130E** are connected via flow lines to corresponding injector ports **140A-140D** and the loadlock injector port **150**. The plurality of injector ports **140A-140D** and the loadlock injector port **150** may be located proximate to the gate valves disposed between the wafer handling chamber and the different chambers.

Operation of the plurality of isolation valves **120A-120E** and the plurality of flow restrictors **130A-130E** may affect flow of a purge gas into the wafer handling chamber **100**. For example, if the isolation valve **120A** is closed, the purge gas would only travel through the flow restrictor **130A**, leading to a lower flow of purge gas in comparison to when the isolation valve **120A** is fully open.

An even distribution of purge gas may be achieved if each of the gate valves is closed and each of the plurality of isolation valves **120A-120E** is closed. In this case, all of the purge gas would flow through the plurality of flow restrictors **130A-130E**. A low even flow of purge gas would be evenly distributed among the plurality of flow restrictors **130A-130E**.

In the situation where one semiconductor wafer is being transferred from the reactor chamber to the wafer handling chamber **100**, a higher flow of purge gas may be necessary. If the semiconductor wafer passes through the gate valve associated with the injector port **140A**, it may be beneficial to have a higher flow of purge gas passing through the injector port **140A**. This may be achieved by opening the isolation valve **120A** and keeping the other isolation valves **120B-120E** closed.

An additional way to operate the isolation valves **120A-120E** and the flow restrictors **130A-130E** in accordance with at least one embodiment may be to achieve an inversion of flow behavior. This would result in a low flow if all isolation valves **120A-120E** are open and all gate valves are closed, resulting in an even flow distribution. A high flow would be only achievable in one injector port if the isolation valve associated with that injector port is open and the other isolation valves are closed.

Situations may be possible where the plurality of flow restrictors may be replaced with additional isolation valves. In addition, a plurality of valves in parallel for each injector port may be desirable depending upon flow rates of purge gas desired. Other possibilities may include changing flow at each location with an independent mass flow controller or a pressure flow controller. A flow may be increased at a particular location with particular robot movement instead of actuation of the gate valve. Finally, multiple flow locations may be opened in concert with each other. This may occur where isolation valves to the left and right of the wafer may be opened simultaneously or alternately in order to allow for an increased purge flow at the wafer.

While the figures only show five injector ports, other arrangements of additional injector ports may be possible. For example, a ring of injector ports may be installed to cover an entire path over which a semiconductor substrate travels. A pattern of operating the injector ports in wafer handling chamber may be employed where certain purge sections may be turned on and off.

The particular implementations shown and described are illustrative of the disclosure and its best mode and are not intended to otherwise limit the scope of the aspects and implementations in any way. Indeed, for the sake of brevity, conventional manufacturing, connection, preparation, and other functional aspects of the system may not be described in detail. Furthermore, the connecting lines shown in the

6

various figures are intended to represent exemplary functional relationships and/or physical couplings between the various elements. Many alternative or additional functional relationships or physical connections may be present in the practical system, and/or may be absent in some embodiments.

The subject matter of the present disclosure includes all novel and nonobvious combinations and subcombinations of the various processes, systems, and configurations, and other features, functions, acts, and/or properties disclosed herein, as well as any and all equivalents thereof.

What is claimed is:

1. A wafer handling chamber configured for handling a semiconductor substrate, the chamber comprising:

a housing;

a first gate valve disposed on the housing, wherein the first gate valve is configured to allow the semiconductor substrate to pass and enter into the housing;

a first injector port disposed proximate the first gate valve; a first isolation valve disposed outside the housing and connected to the first injector port by a first flow line, wherein the first isolation valve is configured to adjust an amount of a purge gas flowing through the first flow line to the first injector port; and

a flow controller in communication with the first isolation valve and configured to adjust the amount of the purge gas flowing from the first injector port into the housing, wherein the first injector port, the first isolation valve, and the flow controller are configured to operate together to reduce an oxygen content of the semiconductor substrate based on the amount of the purge gas flowing into the housing, and

wherein in response to closing the first isolation valve, the purge gas continues to flow through the first injector port and the amount of the purge gas flowing from the first injector port into the housing is decreased.

2. The chamber of claim **1**, further comprising a first flow restrictor coupled to the first isolation valve, wherein the first isolation valve and the first flow restrictor are configured to adjust the amount of the purge gas flowing through the first flow line to the first injector port.

3. The chamber of claim **1**, wherein closing the first isolation valve is configured to reduce the amount of the purge gas flowing to the first injector port.

4. The chamber of claim **1**, wherein the purge gas comprises at least one of: nitrogen (N₂); argon (Ar); hydrogen (H₂); and krypton (Kr).

5. The chamber of claim **1**, further comprising:

a second gate valve disposed on the housing, wherein the second gate valve is configured to allow the semiconductor substrate to pass and enter into the housing; a second injector port disposed proximate the second gate valve; and

a second isolation valve disposed outside the housing and connected to the second injector port by a second flow line, wherein the second isolation valve is configured to adjust a second amount of the purge gas flowing through the second flow line to the second injector port, wherein the flow controller is in communication with the second isolation valve.

6. The chamber of claim **5**, further comprising:

a third gate valve disposed on the housing, wherein the third gate valve is configured to allow the semiconductor substrate to pass and enter into the housing;

a third injector port disposed proximate the third gate valve; and

7

a third isolation valve disposed outside the housing and connected to the third injector port by a third flow line, wherein the third isolation valve is configured to adjust a third amount of the purge gas flowing through the third flow line to the third injector port,

wherein the flow controller is in communication with the third isolation valve.

7. The chamber of claim 6, further comprising:

a fourth gate valve disposed on the housing, wherein the fourth gate valve is configured to allow the semiconductor substrate to pass and enter into the housing;

a fourth injector port disposed proximate the fourth gate valve; and

a fourth isolation valve disposed outside the housing and connected to the fourth injector port by a fourth flow line, wherein the fourth isolation valve is configured to adjust a fourth amount of the purge gas flowing through the fourth flow line to the fourth injector port,

wherein the flow controller is in communication with the fourth isolation valve.

8. The chamber of claim 7, wherein closing each of the first isolation valve and the first gate valve, the second isolation valve and the second gate valve, the third isolation valve and the third gate valve, and the fourth isolation valve and the fourth gate valve is configured to produce a substantially even distribution of gas to the first injector port, the second injector port, the third injector port, and the fourth injector port.

9. The chamber of claim 7, wherein opening only the first isolation valve and the first gate valve is configured to produce an increased localized purging at the first injector port.

10. The chamber of claim 7, wherein opening each of the first isolation valve and the first gate valve, the second isolation valve and the second gate valve, the third isolation valve and the third gate valve, and the fourth isolation valve and the fourth gate valve is configured to produce a substantially even distribution of gas to the first injector port, the second injector port, the third injector port, and the fourth injector port.

11. The chamber of claim 7, wherein the first injector port, the second injector port, the third injector port, and the fourth injector port are configured to be selectively operated by the flow controller to allow purging at a particular injector port to be turned on and off.

12. The chamber of claim 1, wherein the flow controller comprises at least one of: a mass flow controller or a pressure flow controller.

13. A system adapted to process a substrate, comprising:

a wafer handling chamber;

a reaction chamber;

a gate valve disposed between the wafer handling chamber and the reaction chamber, wherein the gate valve is configured to allow the substrate to enter the wafer handling chamber from the reaction chamber;

an injector port disposed proximate the gate valve;

an isolation valve connected to the injector port by a flow line, wherein the isolation valve is configured to adjust an amount of a purge gas flowing through the flow line to the injector port; and

8

a flow controller in electronic communication with the isolation valve and configured to adjust the amount of the purge gas flowing through the flow line to the injector port,

wherein the injector port is configured to flow the purge gas into the wafer handling chamber and reduce an oxygen content of substrate based on the amount of the purge gas, and

wherein in response to closing the isolation valve, the purge gas continues to flow through the first injector port and the amount of the purge gas flowing from the injector port is decreased.

14. The system of claim 13, further comprising a flow restrictor coupled to the isolation valve, wherein the isolation valve and the flow restrictor are configured to adjust the amount of the purge gas flowing through the flow line to the injector port.

15. The system of claim 13, wherein closing the isolation valve is configured to reduce the amount of the purge gas flowing through the flow line to the injector port.

16. The system of claim 13, wherein opening the isolation valve and the gate valve is configured to produce an increased localized purging at the injector port.

17. The system of claim 13, wherein the flow controller comprises at least one of: a mass flow controller or a pressure flow controller.

18. A method, comprising:

transferring a semiconductor substrate within a semiconductor processing system from a first reaction chamber to a wafer handling chamber through a first gate valve; opening a first isolation valve coupled to a first injector port disposed proximate the first gate valve;

increasing flow of a purge gas through the first injector port into the wafer handling chamber at least one of before or during the transferring the semiconductor substrate from the first reaction chamber to the wafer handling chamber, in response to the opening the first isolation valve;

closing the first isolation valve, the purge gas continuing to flow through the first injector port after the closing the first isolation valve; and

decreasing the flow of the purge gas through the first injector port into the wafer handling chamber in response to closing the first isolation valve,

wherein the increasing the flow of the purge gas through the first injector port during the transferring the semiconductor substrate from the first reaction chamber to the wafer handling chamber reduces an oxygen content in a film on the semiconductor substrate.

19. The method of claim 18, wherein the decreasing the flow of the purge gas is performed after the transferring the semiconductor substrate from the first reaction chamber to the wafer handling chamber is complete.

20. The method of claim 18, wherein the opening the first isolation valve is effectuated via a flow controller in communication with the first isolation valve.

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